Opportunities for Intelligent Interfaces Aiding Healthcare in Low-Income Countries

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ABSTRACT
Child mortality is one of the most pressing health concerns – almost 10 million children die worldwide each year before reaching their fifth birthday, mostly in low-income countries. To aid overburdened and undertrained health workers the World Health Organization (WHO) and United Nations Children's Fund (UNICEF) have developed clinical guidelines, such as the Integrated Management of Childhood Illness (IMCI) to help with the classification and treatment of common childhood illness. To help with deployment, we have developed an electronic version (e-IMCI) that runs on a PDA. From July to September 2007, we ran a pilot of e-IMCI in southern Tanzania. The system guides health workers step-by-step through the treatment algorithms and automatically calculates drug doses. Our results suggest that electronic implementations of protocols such as IMCI can reduce training time and improve adherence to the protocol. They also highlight several important challenges including varying levels of education, language and expertise, which could be most adequately addressed by implementing novel intelligent user interfaces and systems.

Author Keywords
IMCI, Tanzania, child health, medical protocols, intelligent tutoring, user experience, adaptive interfaces.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
To address the public health issues in low-income countries and aid the overburdened, undertrained health workers, the World Health Organization (WHO) and other non-profits have developed medical algorithms to quickly classify and suggest treatment for major health concerns.

The Integrated Management of Childhood Illness (IMCI) [17] program was developed specifically to deal with high child mortality in low-income countries where almost 10 million children under the age of five die each year [16]. The IMCI treatment algorithm guides health workers through a set of investigations and questions that lead to a classification and recommended treatment. A multi-country evaluation of IMCI, which included a study across four districts in rural Tanzania, found that the correct use of IMCI combined with evidence-based planning leads to rapid gains in child survival rates [1]. Despite this, uptake in Tanzania has been disappointing for a number of reasons, including a lack of sufficient supervision and the cost of training health workers. Although nearly all districts in the country have started to train front-line health staff in the use of IMCI, many health workers remain inadequately trained. For a sick child attending a rural health facility in Tanzania, the chance of being seen by an IMCI-trained person is low.

To aid with the deployment of IMCI, we have developed an electronic version (e-IMCI) that runs on a PDA and guides health workers step-by-step through the treatment algorithm. We piloted the use of our software with four clinicians at a dispensary (small health facility) in rural Tanzania from July to September 2007 to gather quantitative evidence on the effect on adherence to the protocol and qualitative data from clinicians about their impression of the software.

In this paper, we present observations from our field study of e-IMCI and present opportunities for e-IMCI to adapt to user experience, be used for training, and automatically generate fast, usable interfaces for a variety of platforms.

Figure 1: The e-IMCI interface.

IMCI

IMCI is a multi-faceted approach to addressing children's health in a resource-constrained environment. Originally developed by the WHO, UNICEF and other partners in 1992, the system integrates several protocols to address the most common childhood conditions. According to the WHO, 70% of childhood deaths worldwide are caused by pneumonia, diarrhoea, malaria, measles, malnutrition or a combination of these, all of which are covered by IMCI [17].

At the health facility level, IMCI is a medical algorithm currently implemented as an extensive training program and paper chart booklets used in the clinics to aid practitioners at the point of care. To make the algorithm easier to follow, IMCI divides the treatment into five major symptoms: cough, diarrhea, fever, ear problems and malnutrition. Referring to a paper chart, the practitioner asks the caregiver (typically the mother or another family member) questions and performs investigations to navigate through the decision tree. The questions are usually simple—including questions about age, weight, and how long the child has had a particular symptom. The investigations include various medical tasks like taking body temperature or measuring the number of breaths per minute.

e-IMCI

To aid practitioners in navigating through the algorithm, we developed e-IMCI, which runs on Windows Mobile. The software presents one question or investigation at a time and uses the answer to determine the next step. By removing the page-turning involved with the chart books, and automatically calculating drug doses, we believe that the electronic delivery of IMCI can be as fast as the current practice.

The interface for e-IMCI is based on work being done in South Africa, where a screening algorithm is being developed to help counselors in HIV clinics determine which patients need to be seen by doctors and which are healthy enough to be sent home with their drugs [8]. Preliminary results there are also encouraging.

Figure 1 shows the e-IMCI software. Based on familiar instant messaging and chat programs, the interface presents the current question at the bottom of the screen. After answering the question, a short version is presented above the next question, allowing users to review previous answers. This provides context, allowing users to review their previous answers and understand how the system arrived at the next question. Back and next buttons are supplied for correcting errors in previous answers. This interface was also inspired by the DiamondHelp system for collaborative home applications [13].

FIELD STUDY

To pilot e-IMCI, we studied its use with real patients in a dispensary in Mtwara, Tanzania [3]. Four clinicians participated in the full study, which had four major parts. First, clinicians were interviewed to determine their level of experience with computing devices and preconceived notions about using e-IMCI. The software was introduced at this time so clinicians could comment on how they thought that it might or might not help them.

Next, the clinicians were observed following IMCI according to their current practice. The first author took notes during these sessions while a Tanzanian research colleague acted as a translator for the doctor-patient interactions (mostly in Swahili) and as a supervising clinician. The Tanzanian researcher filled out a check sheet to record which investigations were performed and which questions were asked.

After gathering this baseline data on current practices, the clinicians were observed using the e-IMCI software. Again, two researchers took notes.

Finally, the clinicians were interviewed to compare their experience with preconceived notions. They were also asked about long-term use and potential for deployment of the system.

Current Practice in Tanzania

While the ideal case is that the practitioner follows the IMCI paper chart booklet for every patient under the age of five, we found that this is not the case. In our study we observed that many clinicians chose to work without following the paper charts.

Figure 2: e-IMCI being used by a clinician with a patient.

All four of the clinicians that we worked with mentioned the duration of the patient visit as being important. As one clinician put it, they do not like to follow the chart booklet "because it takes so long" to flip the pages and follow the algorithm. One of the more experienced clinicians stated "experience is faster, but [we] can forget some things." The long line of patients queuing outside the room added to the need for quick visit times. We want a device to help clinicians navigate through the algorithm, but it is clear from our experience that it needs to be at least as fast as current practice, where the chart booklet is rarely referenced, as well as having some additional value that will encourage its continued use (e.g., automatically producing government-mandated monthly reports).

Clinician Response

The clinicians unanimously cited the interface as easy to use. One particularly thorough clinician enjoyed being able to review all of his previous answers and would routinely check to make sure he was entering correct data. Figure 2 shows a clinician using the system with a patient during our pilot study.

All of the clinicians cited using e-IMCI as being faster than following the chart booklet, but not quite as fast or flexible as current practice, where care is often delivered from memory instead of explicitly following the protocol. One clinician said that if available she would "use a combination" of current practice and the e-IMCI software and would never need to refer to the book. We were encouraged by the positive feedback from the clinicians, but we feel that we can improve the speed and efficiency of the interface to encourage them to use the software for every patient.

Beyond the Novelty Effect

To achieve long-term use beyond the novelty stage, we propose that two things are required: efficiency and significant additional value. Based on our experience, if the software significantly increases the length of patient visits, it will be put down and only occasionally referenced, just like the chart booklet. The responses we have collected

Figure 3: The clinicians training each other with e-IMCI.

also suggest that experienced e-IMCI users will want flexibility in how to structure/order their interactions with the patient.

However, the system must also deliver additional value to the clinician in order to justify the overhead of purchasing and maintaining the hardware and learning to use the system. By providing longitudinal records, summary reports and a resulting higher standard of care the system can provide a compelling value proposition to clinicians and their supervisors.

OPPORTUNITIES FOR INTELLIGENT INTERFACES

We believe that intelligent user interface research can be used to increase the uptake and effectiveness of this software for day-to-day use, training new clinicians, and implementing more complex and dynamic protocols.

Adapting to User Experience

None of the five clinicians that we worked with had any previous experience with PDAs or computers, though all had used a mobile phone at some point in the past. The clinicians were able to quickly get used to the user interface and the stylus. We demonstrated the device to all clinicians while we were implementing the IMCI protocol. Two clinicians used the software during our pre-trials where we discovered as many major bugs as possible. After finishing our programming, we trained one clinician and answered questions while she used the system. After about 10 to 20 minutes stepping through the software, she took it upon herself to demonstrate the system to her colleagues.

As mentioned earlier, clinicians said they would prefer to use a combination of providing treatment from memory and using the e-IMCI software. When using memory, care is *user-driven*, delivered by user initiative. That is, the clinician decides what investigations to perform and in what order. When using e-IMCI, the experience is *system-driven*, by system initiative, meaning that the clinicians lose a certain amount of flexibility. We propose providing two interfaces to our system that will not only make the software faster to use, but also lead to improved acceptance by the clinicians.

The first mode, *guided mode*, would work like the current interface, with a system-driven approach. The software would be the sole determinant of the order of questions.

The second mode, *expert mode*, would be almost entirely user-driven. Practitioners could choose the investigation they wish to perform. When they feel that they have enough data, they could ask the software for a classification and treatment. The tool would revert back to guided mode for asking any subsequent questions that might be needed to make this determination. This would provide a mixed-initiative scenario, where the user is in charge but the system makes sure that the quality of care is not jeopardized.

Training Support

One of the clinicians we worked with was an IMCI instructor. He found the software "easy to learn [and] easy to use." He felt that using the e-IMCI software instead of the paper-based protocol, people could be trained faster than with current training. If the health workers were previously familiar with PDAs, he felt that he could cut training time by 50% (from the current 11-14 days).

In future work, we plan to expand e-IMCI to include a training module. The Novartis Foundation for Sustainable Development, in conjunction with the WHO, has developed a computer-based training course for IMCI [11]. The course trains health workers to use the paper chart booklets. Within e-IMCI we can provide contextualized feedback and guidance while learning to use the system.

Previous work has shown intelligent tutoring systems (ITS) to be effective learning tools for students [7]. There has been work on using ITS for medical learning [15]. There has also been work using this approach with mobile devices [14]. However, the context of health facilities in rural Tanzania presents a different set of challenges. Not only can language, domain expertise and cultural diversity vary widely among health workers, but the available infrastructure and user experience can present novel difficulties introducing computing technology.

In Tanzania, the official language of the people is Swahili, but the language of the government is English. As a result all of the health reporting must be in English. During an informal tour of health facilities in the Mtwara region, the first author observed health workers with a wide range of English language skills. Some were able to converse while others knew only enough to do the required reporting.

Tanzania has at least nine different levels of health professions from maternal child health aid, which requires a 1-year course after secondary school, to full medical doctor, with an additional 5 years of study after completing secondary school. Over half of these types of professions qualify to be trained to use IMCI in their daily work. Within each of these groups there is a varying range of technical experience and expertise. All the clinicians we worked with this summer either owned or had used a mobile phone. None had any previous experience with PDAs or computers. We expect that almost every potential user will have experience with mobile phones. On the other side of the spectrum, the more technically savvy will already be familiar with email, web browsing and other basic computer tasks.

Finally, Tanzania is made up of over 120 different tribes occupying 26 different regions: 21 on the mainland and 5 on Zanzibar. People often speak their tribal language as their mother tongue, in addition to Swahili, which they learn in school. This wealth of different cultures presents another set of issues. For example, on a previous trip to Tanzania doing health surveys, the first author learned that it is not socially acceptable to ask the Maasai people about the causes of death of their ancestors. These types of cultural differences are present throughout the country and must be carefully considered.

Past the traditional training scenarios, we can imagine that training could be more personalized for the user. If it is a refresher course, the analysis of the use of e-IMCI in the field could be used to influence the re-training received. Similarly, as protocols are updated[1] the software could automatically generate initial and re-training scenarios.

Deploying Protocols

Our studies and those of D-Tree in South Africa have demonstrated that software interfaces for medical protocols can improve accuracy of delivery without a dramatic decrease in speed and offer potential for shorter training times when compared to the paper-based versions. However, it is inefficient to spend weeks reprogramming just to deploy a new algorithm. Ideally, medical professionals would be able to design, update and deploy new protocols without any programming skills.

To make the process of deploying and updating software-based versions of these protocols scalable, we believe that the design of the protocol itself, the paper "interface" and the software versions, should be integrated into a single process. Recent advances in automatic user interface generation [5, 9] make this approach feasible.

As protocols are developed, the software can automatically generate versions for different platforms. In extremely rural locations with no power, we may still need to use

[1] In Tanzania, IMCI is updated annually.

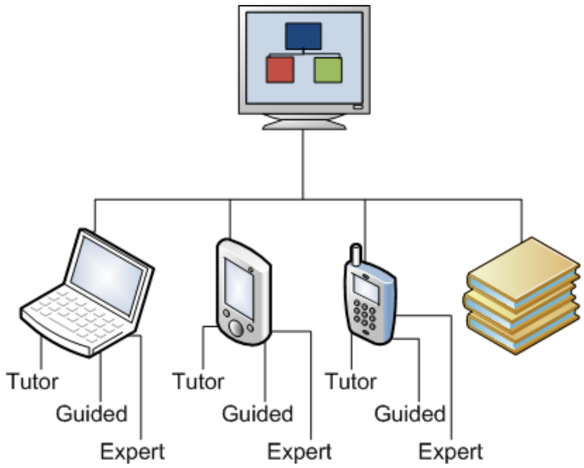

Figure 4: Protocol creation for different devices and interfaces.

paper charts (which could also be automatically generated from an abstract model of the protocol), but in large cities of low-income countries, it may be feasible to use a laptop or desktop machine. We anticipate the majority of health facilities will exist somewhere between these two extremes, using mobile devices like PDAs and smart phones to deliver medical protocols. The paper charts could also be used as a backup in case devices are lost, stolen, broken or unable to be charged.

Further, for each of these devices, we can provide three interfaces: a *tutor mode* for training, a *guided mode* to follow the system-driven model and an *expert mode* to follow the user-driven model. Software to automatically create usable interfaces for these medical protocols would be used widely. With the large number of protocols and clinical algorithms currently being used, three different skill-levels and at least four different device targets, the amount of work required to deploy or update a protocol grows rapidly. Figure 4 illustrates this point, with the protocol originally being designed on the desktop machine and deployed on a variety of devices with automatically generated interfaces. An added benefit of this approach might be improved consistency among interfaces for different protocols [10], which could further reduce training time.

CONCLUSION

Applying information and communication technology in low-income countries as opposed to developed countries provides a unique and challenging set of constraints. As presented in this paper, the delivery of medical algorithms at the point of care in health facilities in rural Tanzania provides a huge opportunity for intelligent user interfaces. In future work we plan to continue the development and deployment of e-IMCI in Tanzania, but hope to also go beyond IMCI to include more complex protocols.

Similar projects, such as the HIV screening algorithm in South Africa, will also benefit from further research in user interface design. More generally, job aids for under-trained, over-burdened knowledge workers in low-income countries provides a rich set of opportunities for user interface research.

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